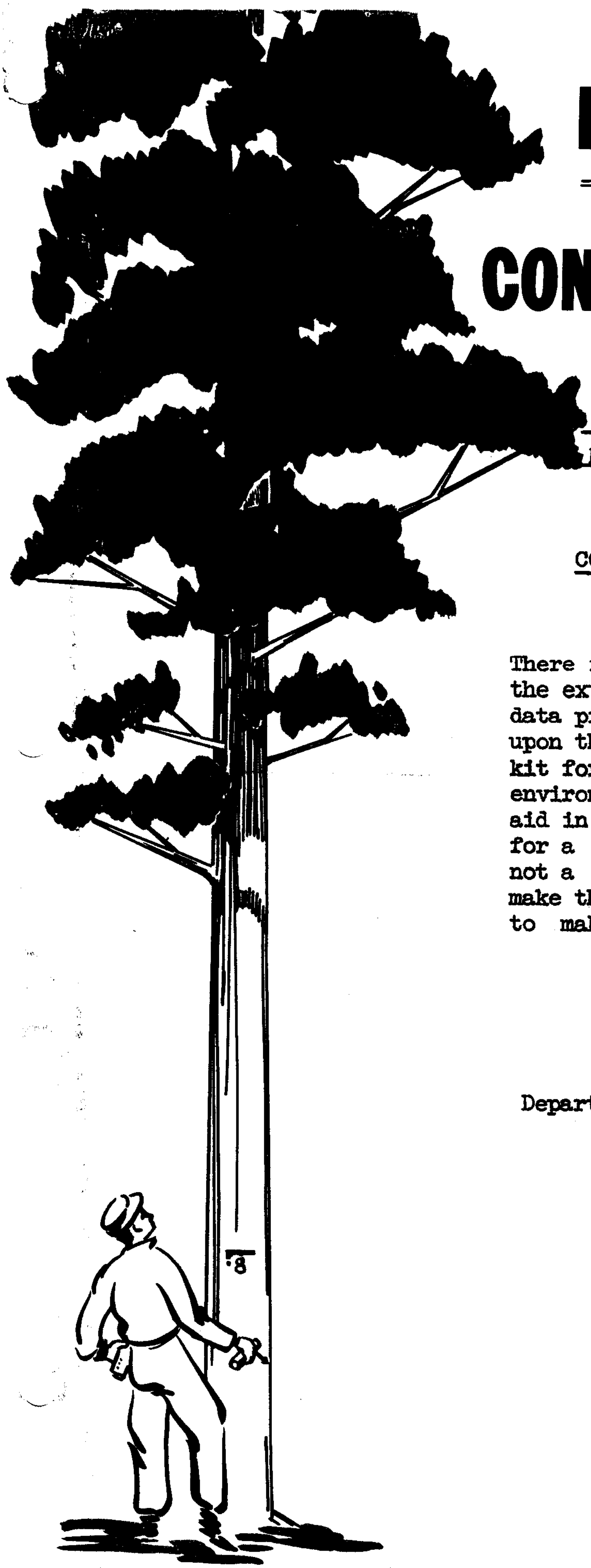

FOREST CONTROL by CONTINUOUS INVENTORY

"Today I have grown taller from walking with the trees."

...Karle Wilson

Milwaukee, Wis. June, 1963 No. 111

COMPUTERS IN FOREST MANAGEMENT

There is a very acceptable ground between the extremes in the acceptance and use of data processing equipment. We can look upon the computer as one more tool in our kit for effective control of our forest environment and our enterprise. It is an aid in decision-making, not a substitute for a decision maker. It is a servant, not a master. We must strive, not to make the man think like a computer, but to make the computer think like a man.

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Computers in Forest Management

CONCLUSIONS

Looking at the implications of computer use and development to the industry at large, one is forced to conclude that an enlarged program of research should be initiated by the wood-using industries immediately, so that these techniques will be closer to a production stage when they are needed. Already research is behind our needs in this area of forest management control. New computer applications need to be tested, and we need to experiment with generalized computer programs already available and make necessary adaptations. Another question that must be faced squarely is how to tie this research effort into training channels for getting men trained to put the research results into practice.

To conclude with a few general remarks about the place of computers in making management decisions - there are two extreme attitudes toward computers which need to be avoided. One of these is the view that any answer which comes from a computer has a certain sanctity, and should be followed precisely, whether all the reasons for it are understood or not. Actually, input data can contain errors, and programs are no better than the assumptions behind them and the men who write them. Very close liaison between programmers and operating personnel is vital. Computer output should always be checked against experienced judgment, and computer results that widely deviate from usual patterns should be thoroughly analyzed before they are converted into action programs.

At the other extreme is the fearful attitude that management will be "computerized" and impersonalized, or that the forest is essentially a biologic community and that the use of computers and mathematical formulations will override basic biologic and ecologic considerations. In this view any data that has been through a computer and any decision from a system including a computer is distrusted. Those holding such a view fail to take advantage of the great power of a computer to rationalize a mass of data too intricate for the human mind to handle. The fact is that data processing on a computer can allow management to consider a great many more careful biological observations than it possibly could otherwise. Current trends seem to indicate that better data gathering and analysis will lead to marshalling economic resources behind the application of our accumulated biological knowledge, rather than lead to ignoring it.

In short there is very acceptable middle ground between the extremes. We can look upon the computer as one more tool in our kit for effective control of our environment and our enterprises. It is an aid in decision-making, not a substitute for a decision maker. It is a servant, not a master. We must strive not to make the man think like a computer, but make the computer think like a man.

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Computers in Forest Management

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A forest property operated under one management, especially a large industrial forest, is an abstract thing. It is much more abstract in the problems it presents than many businesses. The manager of a large factory or a big department store can visit frequently all parts of his enterprise and visually check the efficiency of its operation. It is somewhat easier for him, than for the forest manager, to see most parts of his organization in a short time and to conceptualize the entire process he is trying to control.

A forest, however, is never seen in anything like its entirety. In spite of our efforts with maps and aerial photographs the woodlands manager has difficulty achieving a comprehensive view of his operation so he may compare and correlate its many parts. Have you ever noticed the scarcity of pictures in a forest management textbook in comparison to books on logging or fire protection or insects or silviculture? Add to this great spread of area the greater time distribution in many factors of forest management. Then the unusually abstract nature of the forest, or as we are growing to recognize, of the entire operating system of wood supply, becomes evident. It can only be comprehended and visualized and controlled through large numbers of individual observations compiled and analyzed into charts, graphs, tables, and figures of profit, loss, and rates of return. Much data processing therefore is an essential part of woodlands control, and the digital computer becomes a natural ally of the manager.

Computer a Regular Tool of Management

My purpose is to show you the computer as an integral part of the forest management control system - not as a research tool aiding in studies of certain techniques that may or may not be utilized, but as a regular implement in the day-to-day and year-to-year decisions of administration. Indeed, as we anticipate the use of the more complex methods of operations programming and decision theory in optimizing returns from an entire wood supply system, the computer becomes indispensable.

I do not mean to imply that computers should be used on all forest management problems. Only in certain types of situations will the computer be useful and efficient. In many types of problems hand methods or desk calculators are most appropriate. A computer is useful only when repetitive calculations must be made, either in repeating a simple process a great many times, as in making out a payroll for many people with all their differing deductions, or when a more complicated calculation must be carried out at regular intervals, such as checking error of closure on a surveyed traverse or figuring cut and fill in road planning.

Writing, checking, and debugging a computer program is complex and time-consuming enough that it will usually take much more effort than can be saved by the great speed of the computer in one run of a calculation. But when the calculation process is exactly the same each time, except that new data is used, one program will suffice, and the high fixed cost of program preparation is spread over many repetitions and compensated by the tremendous speed of the computer.

Some Computer Applications in Forest Management

While I have been requested to spend most of my time describing in some detail certain applications of the computer developed while working with Hiwassee Land Company, I might mention a few other examples of situations in which computers have found use. An example of the first type, many repetitions of a relatively simple calculation, is the computing of tree volumes in forest inventory. Incidentally, all other parts of summarizing forest inventories have also been handled by computers. The computer has made the standard volume table obsolete in much inventory work. Instead volume equations are used, and these may be as complicated as one may wish to make them, for the computer takes practically no more time to solve an 8-variable formula than a 2-variable formula. In fact this possibility of using the computer has raised a whole new concept of tree volume calculation - to calculate the exact volume of each tree from its individual measurements, rather than applying averages from many trees (Grosenbaugh, 1954).

Two examples of the second type of application - periodic repetitions of a complicated calculation - can be found in the western timber region. Both applications were initially made on the IBM 650. One is a program to calculate values per thousand board feet for logs of various sizes and grades as new mill study data becomes available and as market prices change. This information is used in keeping timber appraisals up-to-date (Frazier and Carney, 1961).

The other example is an application by the Oregon State Forest Division of a computer program to place valuations on immature stands of timber which the state is considering for purchase (Hunt and Bell, 1961). This program has the interesting feature of first figuring the rate of interest earned by the prospective timber crop and then using this rate for discounting future net incomes to present appraised values.

One of the big advantages of computer use has been the speed with which data may be summarized and placed in the hands of the men who can use it. Of course this advantage is also gained from regular punch card equipment without the computer, but it can accelerate the process. One company has capitalized on this possibility so that in the course of a comprehensive inventory of all its lands, as each district forester completed his field work, summary sheets for his district were back in his hands within several weeks, so he could use the information in his everyday management, long before the inventory for the entire property was completed. Another company gained an appreciable capital loss benefit on income taxes a few years ago, when ice damage was so widespread, by quickly examining all its CFI plots and summarizing the data on machines to make an estimate of total damage.

Rate of Earning Computations

Another computer application that will be of value to forest management is a program recently developed at Purdue for calculating the interest rate earned in any complex long-range investment in which all costs and incomes are known or can be estimated. By complex investment is meant an investment with many different items of cost and income in different years, spreading the life of the investment over a long period of time. Such situations are common in forestry, an example being the planting and eventual harvesting after 30 or 40 years of a stand of pines.

We do not have time to go into the details of how the program works, or a complete interpretation of the printed output sheet. What is important is the usefulness of the program. It enables the industrial forest manager to use rate of return as the basic guide in choosing between many activities in which he might invest, and since this is the criterion on which many corporate alternatives are being judged, he is in a position to compete for capital on the same basis as other portions of his company. Perhaps most significant is the fact that this procedure enables one to compare alternatives without the questionable assumption we have so frequently had to make in the past of an alternative rate of return. No such figure is needed here. I might add that this approach has been in the forest finance books for the past 30 years, but it has been so lengthy to apply by hand in practical situations that it has largely gone unused. The computer can eliminate these lengthy and involved hand computations.

Actual machine time involved in the computation discussed is about 15 seconds on the UNIVAC SS-80, on which the program has been running.

Computer Applications in Forest Control at the Hiwassee Land Company

The remainder of this talk will be devoted to describing several uses of the digital computer made in the course of work done in cooperation with the Hiwassee Land Company. But first it will be desirable to explain in a general way the forest management system Hiwassee is using, to give a setting for understanding the computer applications.

Hiwassee controls 500,000 acres of land, distributed over 5 states, for which the primary objective is wood supply for the Bowaters mill at Calhoun, Tennessee. This area is subdivided into 27 administrative compartments which are further broken down into "management units" for mapping purposes. The smallest subdivision is the operating block, which is laid out according to ownership boundaries, topographic features, and considerations of access. In setting up these blocks initially the aim was an ideal size of 500 acres, but due to irregularities in ownership patterns and other factors the actual sizes vary from 40 acres to over 1,000 acres.

The overall objective of management is to convert in one rotation each block into a well-stocked stand of pine, to the extent that site considerations allow it. Seven per cent of the area will be left in its present hardwood forest type, but the remainder will be handled as even-aged pine stands on a 35-year rotation. Over 100,000 acres have already been planted to pine since acquisition began, so that considering existing natural pine stands plus plantations, they are in the tenth year of the first rotation.

A complete CFI inventory with permanent plots was installed in the fall and winter of 1960-61, under the direction of Don DenUyl, who as a member of the company's forestry staff has participated in all the activities being reported here. All data from the CFI inventory was processed and summarized on standard punch card equipment, except that tree and plot volumes were computed on the IBM 650 at the University of Georgia, with the help of Jim Bamping. The information from these inventory plots was therefore available to help in further planning by the spring of 1961.

Thus a system of area control with even-aged silviculture was in operation for the major timber type - pine. While this is quite simple in its broad concept, involving planting 1/35th of the area each year, the application of it can get very complex, if one wishes to get the maximum wood supply or dollar return from existing stands. So the question immediately arose of which stands should be cut and replanted first. The major step in solving this problem was taken by the Hiwassee forestry staff itself, primarily Dick Dyer, Louis Camisa, and Gene Hill, in establishing a policy of converting stands in the order of their productiveness, beginning with the least productive. To implement this policy they established a priority rating system, scaled from 0 to 100, based upon the best information that could be gathered on growth rates of stands of various sizes and densities.

It is important to recognize that this rating system was used to establish the order in which stands would be cut, but that other factors were considered also in determination of the exact date of cutting. The operating blocks as they were laid out contained several condition classes, yet the management system intended to convert the entire block as nearly as possible to a single age. It was necessary to determine a priority rating for the entire block, which was done by taking an average rating for the block, weighting the priority rating for each stand by the acreage covered. I believe that the development and acceptance of this idea of a priority system is a real contribution to the techniques of forest management control, and should be recognized as such. It will find more use as we go on to using increasingly complex methods of mathematical programming.

In the summer of 1961 began the complete type mapping of all company lands, using aerial photographs and ground checking. Completion of this would take six months to a year, but for planning and coordination of wood procurement and land management it was desired to know as soon as possible what pattern of wood flow from company lands could be expected for the next 25 years, as a result of following the weeding and planting sequence dictated by the priority system. The forestry staff was asked if such a 25-year projection could be made on the basis of the data then available from the CFI plots. The projection was made, and it required two procedures in which you might be interested, one of which involved the computer.

Monte Carlo Technique

The first of these was an application of the so-called Monte Carlo technique of operations research. Since 100% type mapping was not yet available, there was no way to know what combination of priority classes would be found in each operating block, and therefore what sequence cutting should follow. But by expanding each CFI plot to equal one operating block, and by using a chance method to associate five other priority ratings with that of the timber type on the CFI plot, we arrived at an average priority rating for each plot. The box of numbered beads we used for the chance drawings represented the forest types in the proportions they were found in the particular forest district in which the plot was located, that proportion being determined by the type distribution of the CFI plots. While this chance priority assignment might be very much in error for the cutting date assigned to any one plot, it yielded a priority pattern that should be quite close to reality for the entire property. From this priority rating of each plot (expanded to the acreage of a block) a cutting schedule for the next 25 years was made.

Projection of Wood Flow and Cash Flow

The second procedure we used to make the projection of wood flow involved the computer in two different ways. We had a description of present stands from the CFI plots, but no way to project growth on these stands into the future. It was necessary to develop two sets of projection equations, one for pines and one for hardwoods.

The pine equations were based on those of Schumacher and Coile (1960) in their book "Growth and Yield of Southern Pines". However, their equations were constructed for the coastal plain, not the Tennessee Valley, so some adjustments were necessary. The tree volumes given did not check with the volumes found on Hiwassee plots, and their tree counts per acre included all trees down to $\frac{1}{2}$-inch in d.b.h., whereas the CFI inventory had taken only trees down to 5" d.b.h. Additional field checks were necessary to obtain adjustment factors for this latter condition.

At this point I would like to pause to pay tribute to the contribution of Schumacher and his collaborators in publishing this set of growth and yield equations. I do not believe their significance has been adequately recognized by foresters and others. The significance is especially great for the possibilities of handling forestry decision problems on computers. All the relationships of site, stocking, growth, yield, and tree volume are stated as mathematical formulas; there are no hand-fitted curves, alinement charts, harmonized curves, etc. The entire process can be carried on by a computer, without recourse to looking up values in tables or on charts. While the specific numerical coefficients in his equations will be changed and different variables added as more data is accumulated and as other forest conditions are analyzed, this demonstration of how these relationships can be completely quantified is a major step forward in making forestry more scientific.

To return to our growth projection problem, we still have no way to estimate growth on hardwoods. Existing yield tables don't apply, because age was not usable as a variable. The only source of growth information seemed to be a large number of increment cores taken by the TVA Forestry Division. From these were selected applicable data for the areas and hardwood forest types in which Hiwassee had land. Those data were used to project stand tables from Hiwassee permanent plots by 5-year intervals to cover a 25-year period. Volumes at each 5-year interval were calculated. Then, using a regression program for the IBM 1620 at Purdue, a set of growth equations was developed that would give predicted hardwood volume in any stand at any future date for which cutting is planned.

These hardwood equations were included in a program with the modified Schumacher pine equations to give a single computer program that will project stand data to give an estimate of volume at any date in the future. This projection program was originally used on an IBM 7090, but later on the IBM 1620. The projection program was applied to the Monte Carlo schedule for CFI plots to give an estimate of wood flow from all natural stands. To this was added a separate estimate of yields from thinning pine plantations on a certain fixed schedule. The resulting total wood flow pattern, for both pine and hardwood, for the next 25 years not only gave top management a dependable picture of wood supply from company land for that period, to help in planning for associated wood procurement, but was also converted to dollars to show the expected cash flow from its woodland investment.

Program for Scheduling Actual Field Operations

During the past summer 100% type mapping was completed, and it was possible to apply the priority rating system to actual operating blocks, using the stand distribution present in each block. After block rating was completed, a new schedule of actual blocks was to be made, following by new and more accurate projections the 25-year wood flow.

It had been anticipated that scheduling of operating blocks for weeding and replanting would be relatively simple, involving merely taking them in order of their priority rating until 1/25th of the remaining area was assigned for each year. Four of us optimistically gathered in a room with a desk calculator, two adding machines, a blackboard, and the cards for the nearly 1500 operating blocks to be assigned; we thought that one, or at the most, two days would suffice for the scheduling. After a week of 12-hour days we emerged - - - without the schedule. But we had learned enough about the scheduling problems involved to feel that a computer program could be written to do the job. Looking back, I doubt that a computer program could have been written without that lengthy session of grappling with the many minute problems first-hand, and seeing how they were inter-related.